Arch. Environ. Contam. Toxicol. 49, 274–282 (2005)
DOI: 10.1007/s00244-004-0111-3

ARCHIVES OF
Environmental
Contamination
and Toxicology

Polychlorinated Biphenyls and Organochlorine Pesticides in Human Adipose Tissue and Breast Milk Collected in Hong Kong

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Received: 22 May 2004/Accepted: 4 January 2005

Abstract. Contamination from persistent organic pollutants is a pervasive global problem that urgently demands global concern and action. In the present study, concentrations of organochlorine (OC) pesticides and polychlorinated biphenyls (PCBs) were determined in 37 samples of female adipose tissue collected in Hong Kong hospitals. Among the pollutants analyzed, DDTs (2.79 ng/g fat), HCHs (0.72 ng/g fat), and PCBs (0.19 ng/g fat) were prominent compounds in most of the adipose tissue. *p,p′*-DDE and hexachlorinated biphenyls were found in all samples, whereas heptachlor epoxide and dieldrin were found only in some samples. An estimation of toxic equivalency concentration (TEQ) due to dioxin-like coplanar PCBs was also performed. The estimated TEQ_{PCBs} was 2.01 pg/g fat. This study also compared our previous results obtained from the milk samples of the same donors. Significant correlations are obtained for DDTs and HCHs between milk and adipose tissue. Detailed review of available information concerning OC pesticides and PCBs in different ecological compartments indicated that bioconcentration and biomagnification of these contaminants are common phenomena of the Pearl River Delta region, which has undergone rapid socioeconomic change in the past 20 years. It is suggested to establish a regional organization in order to coordinate the monitoring of persistent organic pollutants in the region.

Polychlorinated biphenyls (PCBs) and organochlorine (OC) pesticides are lipophilic stable toxic compounds that occur in most environmental compartments including soil, water, sediment, and biota (Loganathan and Kannan 1994). They were synthesized chemicals for different applications, e.g., DDT, synthesized in 1939, is a well-known OC insecticide that has a broad range of agricultural and nonagricultural applications worldwide. Many countries banned the use of DDT since the 1970s (WHO 1979), but it is still used in certain parts of the world to control vector-borne diseases, such as malaria. PCBs are a group of synthetic chlorinated biphenyls. Owing to their nonflammable and insulating properties, they have been used widely as coolants and lubricants in transformers, capacitors, and other electrical equipment. Many countries stopped the manufacture of PCBs beginning in the 1980s because there was evidence that PCBs built up in the environment, causing harmful effects on environmental and human health (SRC 1987).

Upon release into the environment, OC pesticides and PCBs will enter soil, water, or air. They are essentially immobile in soil due to the fact that they are strongly adsorbed onto the surface layer of soils. Likewise, as a consequence of their extremely low water solubility, they are also adsorbed onto particulates in water and settled into sediments. They can undergo long-range transport through the atmosphere in a process known as "global distillation," where they migrate from warmer regions to colder regions through repeated cycles of volatilization from soil and water surfaces followed by deposition of these pollutants onto surfaces through dry and wet deposition processes (Ritter *et al.* 1995). Once PCBs and OCs pesticides enter the biological system, they tend to accumulate and biomagnify in higher trophic level organisms (Tanabe *et al.* 1983; Elliott *et al.* 1988). Because humans occupy the top position in the trophic levels, they are obviously exposed to a higher level of these contaminants from aquatic and terrestrial food chains (Travis *et al.* 1988; Loganathan *et al.* 1993). Our previous study indicated that the mean levels of *p,p′*-DDT (Hong Kong: 0.39; Guangzhou: 0.70 μg/g fat), *p,p′*-DDE (2.48; 2.85), and β-HCH (0.95; 1.11) contained in human milk samples collected from Hong Kong and Guangzhou, two large cities located in south China, were 2–15-fold higher when compared with studies conducted in UK, Germany, Sweden, Spain, and Canada (CKC Wong *et al.* 2002).

OC pesticides and PCBs have also been detected in human adipose tissue in some countries, including the United States (Archibeque-Eagle *et al.* 1997), Korea (Kang *et al.* 1997), Japan (Minh *et al.* 2000), and China (Nakata *et al.* 2002). Direct measurement of OCs and PCBs levels in adipose tissue of human populations is good indicator to show the extent of exposure to the chemicals, and evaluate the health hazards. The present study attempted to estimate the body burden of

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these pollutants in the adipose tissue of a group of mothers who have given birth, in Hong Kong. The concentrations of these contaminants in adipose tissue will be compared with those contained in the milk samples collected from the same donors, to see whether there was any correlation between the two.

Together with our intensive studies of OC pesticides and PCBs in different ecological compartments of the Pearl River Delta (Liang *et al.* 1999; Zhou *et al.* 1999; Wong CKC *et al.* 2000; Wong CKC *et al.* 2002; Wong and Poon 2002), assessment of these deadly pollutants in the region will be also addressed.

Materials and Methods

Chemicals

All solvents and reagents used were pesticide-scan grade, Bio-Beads S-X1, 200–400 mesh (Bio-Rad Laboratories) and florisil, 60–100 mesh (Mallinckrodt) were used for sample cleanup processes. Anhydrous sodium sulfate was cleaned and activated at 450°C for 4 h. Florisil was activated at 130°C for 6 h. Reference chemical standards (16 organochlorinated pesticides, PCB congeners, Aroclor 1242, 1254, and 1260) were purchased from ChemService and Accu-Standard.

Samples

Female adipose tissue samples (about 10 g) of ethnic Chinese residents living in Hong Kong were taken from their abdomen during their Cesarean operations from June 1999 to July 2000. A total of 37 samples were taken from patients age 33.9 ± 33. The samples were preserved with 2 ml of 37% formaldehyde and stored in a −20°C freezer until extraction.

Extraction

Each frozen sample was weighed in a 100-ml reagent bottle and homogenized with 10 g anhydrous sodium sulfate with a stainless steel blender for 1 min. The sample was then extracted with 50 ml 1:1 acetone and hexane in a shaking incubator at 40°C for at least 12 h. The extraction process was repeated twice. The extract was then concentrated to 5 ml using a rotary evaporator at 80°C. One fifth of the concentrated extract was used for fat content determination.

Cleanup

Gel permeation chromatography (Gilson) was used to remove the residual fat content in the extract. The remained extract was then added to a GPC glass column packed with preswollen and washed Bio-Beads S-X1 corresponding to 70 g dry material using dichloromethane as eluant (modified from USEPA Solid Waste Analysis) (USEPA 1996a). The extract was then further cleaned with a micro-florisil column with 15 ml of 1:1 hexane and dichloromethane (modified from USEPA Solid Waste Analysis) (USEPA 1996b). The cleaned extract was concentrated to 2 ml and added with GCMS internal standard.

Gas Chromatograpy–Mass Spectrometer Analysis

GC/MS analyses were performed using Agilent 6890 gas chromatography equipped with an Agilent 5970 mass spectrometer. A 30 m × 0.25 mm × 0.25 μm crosslinked with 5% phenylmethyl silicone (HP 5MS) capillary column was used for compound separation. The GC/MS was operated in the selective ion monitoring mode for chemical identification and quantification. Two different GCMS programs were used to determine PCBs and OC pesticides separately. Sixteen OC pesticides including aldrin, α-HCH, β-HCH, δ-HCH, γ-HCH, 4,4′-DDD, 4,4′-DDE, 4,4′-DDT, dieldrin, endosulfan I, endosulfan II, endosulfan sulfate, endrin, endrin aldehyde, endrin ketone, heptachlor, and heptachlor epoxide were analyzed. Results for total DDTs and HCHs were the sum of 4,4′-DDD, 4,4′-DDE and 4,4′-DDT and α-HCH, β-HCH, δ-HCH and γ-HCH, respectively. Aroclor 1242, 1254, and 1260 were used to determine retention times of total PCBs. Total PCBs detected were summed as mono, di, tri, tetra, penta, hexa, hepta, octa, nona, and deca–PCBs. Different congeners were also monitored in the samples for the study of WHO-toxic equivalency concentration (TEQ) of dioxin-like PCBs.

Quality Control

At regular intervals, solvent blanks were subjected to the entire analytical procedures to determine background interference. Reference materials and solvent spike samples were used to check extraction efficiency and recoveries from GPC and florisil cleanup (Archibeque-Eagle *et al.* 1996). Two reference materials (milk powder CRM 178 and 450) were analyzed with 93 ± 23% of the certified values of PCBs and DDTs. Recoveries of PCBs and DDTs were 92 ± 13% and 89 ± 9%, respectively, for the solvent spike samples.

Statistical Analysis

Statistical analyses were conducted using SPSS version 8. Concentrations of PCBs and OC pesticides were expressed as arithmetic means ± standard deviations. Descriptive statistics were used to characterize the pollutants in samples of human adipose tissue and milk. T tests were performed to assess the relationship between pollutants in the two different types of samples. Spearman rank correlation coefficients were calculated to assess statistical significance of the correlation coefficients for paired samples.

Results and Discussion

Concentrations of PCBs and OC Pesticides in Human Adipose Tissue

PCBs were detected in all adipose tissue samples, Among the 16 selected OC pesticides tested, only β-HCH and *p,p*′-DDE were found in all samples. Some samples also contained trace amounts of dieldrin (3 samples with 0.009 ± 0.006 μg/g fat), heptachlor epoxide (15 samples with 0.006 ± 0.002 μg/g fat), and *p,p*′-DDD (31 samples with 0.053 ± 0.037 μg/g fat) (Table 1).

Table 2 compares the present results with results obtained from other countries. The level of PCBs of Hong Kong samples is similar to that from China, which is relatively low compared to developed countries. It might be due to the slower

Table 1. Mean concentrations (ng/g fat) of organochlorine (OC) pesticides and polychlorinated biphenyls (PCBs) in adipose tissue in Hong Kong population

	Pollutants	Conc (ng/g fat)	Occurrence freq.
PCBs	Tetra-CBs	5 (0–16)	81%
	Penta-CBs	18 (0–56)	94%
	Hexa-CBs	98 (12–310)	100%
	Hepta-CBs	62 (6–174)	100%
	Octa-CBs	5 (0–48)	24%
DDTs	*pp′*-DDD	45 (0–27)	84%
	pp′-DDE	2620 (294–7294)	100%
	pp′-DDT	127 (0–46)	95%
OC pesticides	β-HCH	512 (9–2109)	100%
	γ-HCH	7 (0–151)	11%
	Heptachlor epoxide	3 (0–11)	41%
	Dieldrin	9 (0–15)	8%

Table 2. Comparison of mean concentrations (μg/g fat) of organochlorine pesticides and polychlorinated biphenyls (PCBs) in human adipose tissue collected from various countries

Country	Age	Number	Adipose tissue from	ΣPCBs	ΣDDTs	ΣHCH	Survey year(s)	Reference
HK	26–40	37	A	0.19 ± 0.12	2.79 ± 2.05	0.72 ± 0.51	1999–2000	Present study
China	48–91	5	M	0.07 ± 0.04	7.60 ± 5.80	7.40 ± 6.10	2001	Nakata *et al.* 2002
Finland	19–95	27	A and M	0.50 ± 0.55	0.58 ± 0.74	0.20 ± 0.80	1999	Smeds and Saukko 2001
Japan	50–87	14	N	1.71 ± 0.82	0.78 ± 0.46	0.33 ± 0.18	1998	Minh *et al.* 2000
Mexico	18–44	60	A	—	5.66 ± 5.02	0.16 ± 0.12	1998	Waliszewski *et al.* 2001
Italy	47 ± 21	18	N	0.36 ± 0.22	1.98 ± 2.80	0.34 ± 0.71	1997–2000	Mariottini *et al.* 2002
Belgium	32 ± 4	46	A	0.37	0.51	0.03	1996–1998	Pauwels *et al.* 2000
Greece	—	107	A	0.42	2.47	0.32	1995–1996	Kamarianos *et al.* 1997
Korea	34–72	32	N	0.41 ± 0.18	1.11 ± 1.24	0.41 ± 0.18	1994–1995	Kang e*t al.* 1997
USA	All ages	617	N	0.63	2.517	0.18	1985–1986	Lordo *et al.* 1996

Note: A, abdominal adipose tissue; M, mammary adipose tissue; N, not specified.

Table 3. Relationships of persistent organic pollutants in human breast milk and adipose tissue (ng/g fat)

Location	Year	No.	Pollutants	Breast milk	Adipose tissue	Reference
Hong Kong	1999–2000	26	PCBs	74 ± 58	177 ± 111	Present study
		26	DDTs[a]	3270 ± 2450	2990 ± 2360	
		26	HCHs[a]	1011 ± 891	746 ± 542	
Mexico	1999	60	DDTs[a]	4700 ± 5870	5660 ± 5020	Waliszewski, *et al.* 2001
		60	HCHs	60 ± 50	160 ± 120	
Kenyan	1986	11	DDTs[b]	5910	4860	Kanja *et al.* 1992
		11	PCBs	N.D.	N.D.	

[a] *t* test: significant difference, $p < 0.05$.
[b] Wilcoxon test: significant difference, $p < 0.05$.

pace of industrialization in Hong Kong (1970s) and China (1980s), compared to developed countries (1950s and 1960s). In addition, PCBs production was banned in the late 1970s globally.

Nevertheless, the level of total DDTs of the Hong Kong population is higher than in samples tested in all other countries, except China and Mexico. The high level of DDT in Mexico is understandable because DDT was widely used for malaria control, which has been banned recently (Diaz-Bamga *et al.* 2003). However, an unexpected high level of total DDTs is noted for the study conducted in China. This is possibly due to the fact that there may be some illegal use of DDT in China (even though it was banned in 1983), in addition to the fact that China has requested exemption from the Stockholm Convention for the production and use of DDT as an intermediate and for vector control (Wong MH *et al.* 2002).

Other studies also reported higher levels of DDTs in different environmental compartments of our region, e.g., marine water (Yang *et al.* 1997) and sediment (Hong *et al.* 1995). Because most of the food sources consumed in Hong Kong come from China, therefore high levels of DDTs are obtained for the Hong Kong population (CSD 1999–2000). A similar pattern is also found in the levels of total HCHs for Hong Kong and China populations.

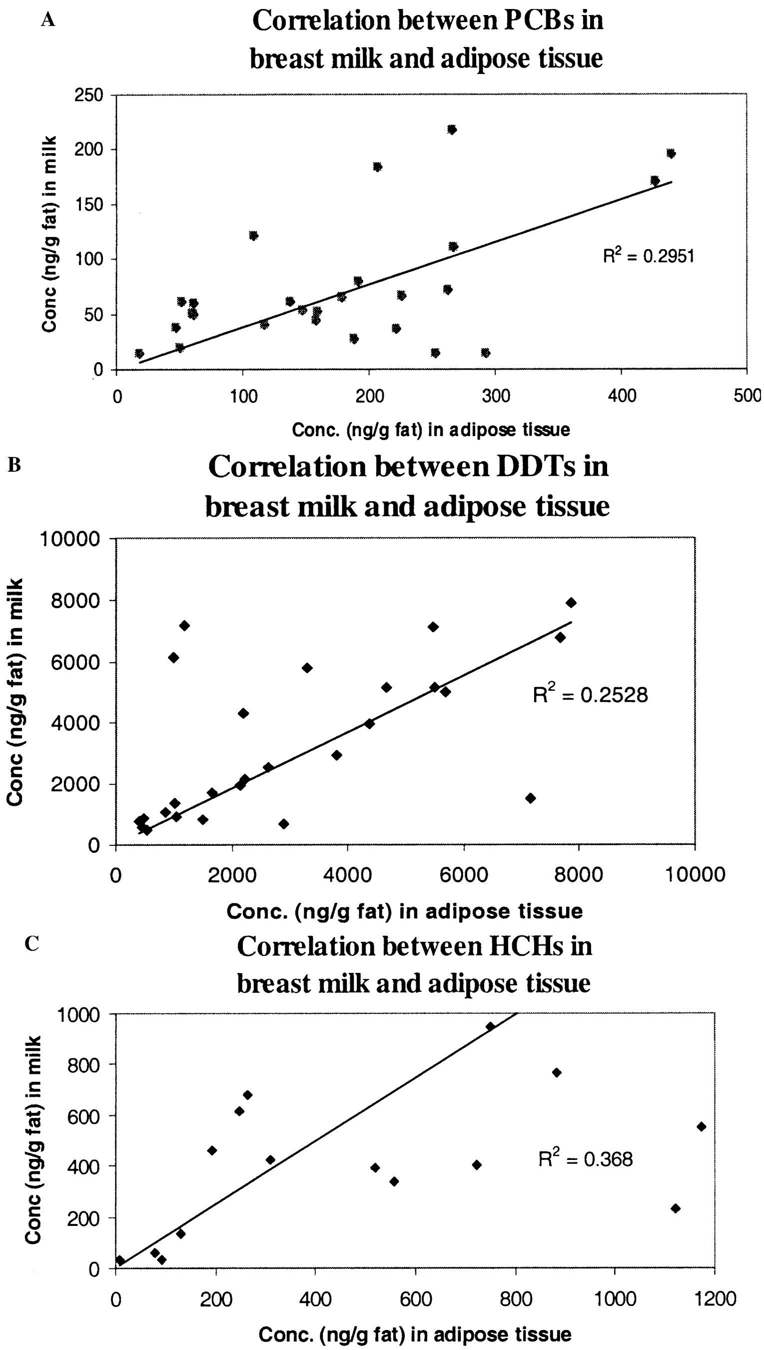

Fig. 1. Correlation coefficients of (a) PCB, (b) DDT, and (c) HCH concentrations between human adipose tissue and milk samples.

Survey year and age of donors are important factors for studying persistent organic pollutants (POPs) in the adipose tissue. Reductions of POPs contaminants have been reported in several time-trends studies (Choi *et al.* 2002; Loganathan *et al.* 1993; Lundén and Norén 1998; Robinson *et al.* 1990; Ott *et al.* 1999), Most POPs contained in adipose tissue revealed a decreasing trend reported by different countries. Because dietary intake is a major route to increase POPs level in the body (Rappe 1992), age of donors needs to be considered for studying body burden of POPs. Our previous study on human milk also showed that concentrations of HCHs, DDTs, and PCBs increased according to the increase of age of donors (Wong CKC *et al.* 2002).

Relationship of PCBs and OC Pesticides in Human Milk and Adipose Tissue

A total of 26 pairs of samples (human milk and adipose tissue) were used to study their relationship with POPs contamination. Table 3 lists the average values of PCBs (milk—74; adipose—177 ng/g), DDTs (milk—3270; adipose—2990 ng/g) and HCHs (milk—1011; adipose—746 ng/g), all fat basis. When comparing the sample means using *t* test, there were significant correlations for DDTs and HCHs between milk and adipose tissue. There is a lack of information related to the relationship of POPs in human milk and adipose tissue. Similar results were noted for two studies where positive correlations

Table 4. Concentrations of organochlorine pesticides and polychlorinated biphenyls in different environmental compartments in the Pearl River Delta region

Sector	Location	Survey year	DDTs	HCHs	PCBs	Unit	Reference
River water	Guangzhou (Pearl River)	1998	0.03–0.12	N.D.–0.02	N.D.	μg/L	Wong and Poon 2002
	Shenzhen River	1998	N.D.–0.06	N.D.	N.D.		Wong and Poon 2002
	Hong Kong (North West N.T.)	1998	N.D.–0.01	N.D.	N.D.		Wong and Poon 2002
	Shenzhen River	1994	0.19	0.22	0.89		Yang *et al.* 1997
River sediment	Guangzhou (Pearl River)	1998	22.1–48.3	N.D.	1.9–5.1	μg/kg dw	Wong and Poon 2002
	Shenzhen River	1998	0.9–35.8	N.D.	0.9–6.1		Wong and Poon 2002
	Hong Kong (North West N.T.)	1998	N.D.–38.0	N.D.	0.9–19.8		Wong and Poon 2002
	Pearl River Delta	1997	5.0–91.0	1.2–17.0	11.0–486.0		Yang *et al.* 1997
	Hong Kong inland water	1997	2.82–8.63	0.1–2.07	43–461		Wong *et al.* 2000
Marine water	Pearl River estuary	2000	0.04–0.29	0.04–0.28	0.03–1.06	μg/L	Zhang *et al.* 2002
	Victoria Harbour, Hong Kong	1997	0.002	0.28	0.004		Connell *et al.* 1998
Marine sediment	Hong Kong coastal	1999	—	—	0.21–63.76	μg/kg dw	Wong *et al.* 2000
	Hong Kong near shore	1998	0.3–14.8	0.1–16.7	0.5–97.9		Richardson and Zheng 1999
	Pearl River Delta	1997	2.6–1629	N.D.–2.9	10.2–339		Mai *et al.* 2002
	Victoria Harbour, Hong Kong	1993–1997	—	—	5–40		EPD 1998
	Macau	1996	2.8	Trace amount	—		Zhang *et al.* 1999
Mangrove sediment	Several locations in Hong Kong	2001	—	—	0.5–5.8	μg/kg dw	Tam and Yao 2002
	Mai Po Marshes, Hong Kong	1997	—	—	2.9		Liang 1999
Soil	*Agricultural*						
	Donggun	1999	0.06–0.14	N.D.–13.6	—	μg/kg dw	Wong and Poon 2002
	Guangming	1999	0.02–0.04	N.D.	—		Wong and Poon 2002
	Hong Kong	1999	0.04–0.07	N.D.–4.4	—		Wong and Poon 2002
Food / biota	*Leafy vegetable*						
	Donggun (edible part)	1999	0.8–2.4	N.D.	—	ng/g ww	Wong and Poon 2002
	Guangming (edible part)	1999	0.6–2.4	4.1–17.0	—		Wong and Poon 2002
	Hong Kong (edible part)	1999	2.3–5.0	N.D.	—		Wong and Poon 2002
	Hong Kong market	1984–1997	N.D.–750	—	—		Ip 1990
	Biota						
	Pearl River Delta pond fish flesh	2000	20–380	ND–10	60–480	ng/g fat	Zhou *et al.* 1999
	Maipo marshes shrimp (whole)	1997	—	—	143–268		Liang *et al.* 1999
	Maipo marshes tilapia (whole)	1997	—	—	136–294		Liang *et al.* 1999
	HK inland water tilapia (muscle)	1997	273–422	19–40	2592–3263		Zhou and Wong 2003
	HK aquiculture mussel	2001	640–61,000	2–29	40–710		Monirith *et al.* 2003
	HK edible marine fish (muscle)	1997	240–3376	ND–454[a]	ND–13239		Chan *et al.* 1999
	Marine mammal						
	HK local dolphin (blubber)	1993–1997	9400–19,0300	8–6875	6110–155,000	ng/g fat	Minh *et al.* 1999
	HK local porpoise (blubber)	1993–1997	7010–213,000	36–1467	1090–64,000		Minh *et al.* 1999
	South China sea whale (blubber)	1994	55,820	1650	3020		Parson *et al.* 1999
Human	*Breast milk*						
	Hong Kong resident	2000–2001			5	TEQpg/g fat	Malisch and van Leeuwen 2003
	Hong Kong resident	2001	—	—	3.1–29.9	TEQpg/g fat	Soechitram *et al.* 2003
	Guangzhou resident	2000	3220–5980	700–2600	20–60	ng/g fat	Wong CKC *et al.* 2002
	Hong Kong resident	1999–2000	660–5610	330–1820	10–70	ng/g fat	Wong CKC *et al.* 2002
	Hong Kong resident	1985	13840	15960	640	ng/g fat	Ip and Phillips 1989
	Adipose tissue						
	Hong Kong resident (abdonmal)	1999–0	410–7860	10–2110	20–540	ng/g fat	Present study

[a] Values only include lindane.

Table 5. Estimation of toxic equivalency concentration of polychlorinated biphenyls (TEQ_{PCBS}) of human adipose tissue collected in Hong Kong

Dioxin-like PCBs	Conc. (pg/g fat)[a]	TEF[b]	Sub-TEQ
3,3′,4,4′-TeCB (77)	<200	0.0001	—
3,4,4′,5-TeCB (81)	<200	0.0001	—
2,3,3′,4,4′-PeCB(105)	1310 ± 1680	0.0001	0.131
2,3,4,4′,5-PeCB (114)	310 ± 560	0.0005	0.155
2,3′,4,4′,5-PeCB(118)	11,700 ± 10,930	0.0001	1.170
2′,3,4,4′,5-PeCB (123)	200 ± 320	0.0001	0.020
3,3′,4,4′,5-PeCB (126)	<200	0.1	—
2,3,3′,4,4′,5-HeCB (156)	1070 ± 850	0.0005	0.535
2,3,3′,4,4′,5′-HeCB (157)	<200	0.0005	—
2,3′,4,4′,5,5′-HeCB (167)	730 ± 560	0.00001	0.007
3,3′,4,4′,5,5′-HeCB (169)	<200	0.01	—
2,3,3′,4,4′,5,5′-HpCB (189)	260 ± 260	0.00001	0.003

Note: TEQ_{PCBS} = 2.011 (pg/g fat).
[a] Concentration (mean ± SD) of 37 samples from Hong Kong.
[b] TEF, toxic equivalent factor equivalent to 2,3,7,8-tetrachlorinated dioxin.

of DDTs were obtained between two types of samples (Kanja *et al.* 1992; Waliszewsld *et al.* 2001).

Using the individual pair samples, Figure 1 further shows that there are positive correlations for PCBs, DDTs, and HCHs between milk and adipose tissue, according to Spearman rank correlation coefficients, all with $p < 0.01$. High levels of coherence of the persistent contaminants are in line with other studies (Kanja *et al.* 1992; Skaare *et al.* 1988; Waliszewski *et al.* 2001). It may be concluded that residues of PCBs and OC pesticides in both human milk and adipose tissue could be used as indicators to show human accumulative exposure of these pollutants.

Contamination of OC Pesticides and PCBs in South China

Table 4 summarizes major findings of OC pesticides and PCBs in different environmental compartments (river water and sediment, marine water and sediment, soil, food, biota, and human) of the Hong Kong and Pearl River Delta region. Low concentrations of these pollutants (mostly >0.1 μg/L) were reported in both fresh and marine waters. This is not unexpected because of their lipophilic nature and low solubility in water. The concentrations of PCBs and lindane (HCH) were lower than the maximum contamination levels of 0.5 and 0.2 μg/L respectively stipulated for national primary drinking water by the USEPA (USEPA 2003). In addition, the concentrations of these pollutants in river and marine water were also lower than the Australian and New Zealand guidelines for protection (90% of species protection) of fresh and marine water quality (ANZEC 2000).

Because of their hydrophobia nature, pollutants have a stronger affinity for particulate materials than water. Therefore, the bottom sediments of river, estuarine, and coastal areas constitute the major sink for these pollutants. The concentration ranges for DDTs (0.3–1629 μg/kg dry wt), HCHs (0.1–16.7 μg/kg dry wt), and PCBs (0.2–339 μg/kg dry wt) in river and marine sediments of the Pearl River Delta were very diversified, depending on sampling locations. For example, lower concentrations were found in mangrove sediment (Liang *et al.* 1999, Tam and Yao 2002), when compared with estuarine sediment (Mai *et al.* 2002). Moreover, the highest DDT and PCB levels found in the region were close to the intervention levels established by Dutch or Canadian guidelines, indicating possible ecotoxicological risks.

When comparing the results obtained from inland rivers (Zhou *et al.* 1999) with Mai Po Marshes (Liang *et al.* 1999) in Hong Kong, it was revealed that there was an obvious bioconcentration of PCBs for tilapia (fish) collected from the polluted inland rivers (267–310 μ/4g/kg dry wt in fish, 43–461 μ/4g/kg dry wt in sediment), which were much higher than those collected from Mai Po Marshes (7.2–10.3 in fish, 2.9 in sediment). This indicates that POPs have imposed adverse effects on some local organisms thriving in contaminated sites.

Biomagnification of OC pesticides and PCBs is also observed in the Pearl River Delta, with concentrations of PCBs. DDTs, and HCHs much higher in whales than in mussels and fish observed in the region. Biomagnifications of POPs are also recorded in other countries (e.g., Lake Michigan, USA–Trowbridge and Swackhamer 2002; Svalbard, Canada – Borga *et al.* 2001; Sweden–Berglund *et al.* 2000). It is commonly found that concentrations of OC pollutants in whales are more than 10-fold higher than that in humans. This may be due to the differences in diets. In general, concentrations of OC in aquatic food > meat > dairy products > vegetable > cereals (Abad *et al.* 2002; Focant *et al.* 2002; Kurunthachalam *et al.* 2001; Nakata *et al.* 2002; Tsutsumi *et al.* 2001; Zhang *et al.* 1999). Fish and other aquatic organisms are the major food source for dolphins and whales; therefore, the bioaccumulation of OC would be higher. Some studies also show a positive relationship of fish consumption and body burden of OC (Norén 1983; Grimvallet *et al.* 1997; Wong CKC *et al.* 2002).

Detailed examination of PCB congeners in the adipose tissue of the present results show that concentrations of marker PCBs (28, 52, 101, 118, 138, 153, and 180) are summed up with the value of 159 ± 97 ng/g of fat. Moreover, PCBs 87, 101, 105, 118, 138, 153, 180, 187, and 190 are the predominant congeners, which are similar to the study of specific PCB composition data in Arcolor 1254 and 1260 (Frame *et al.* 1996). Their composition is >90% of the total PCBs in the human adipose tissue. Some of the above major PCBs are dioxin-like PCBs. The dioxin-like PCBs, including four non-ortho (PCB-77, PCB-81, PCB-126, and PCB-169) and eight mono-ortho (PCB-105, PCB-114, PCB-118, PCB-123, PCB-156, PCB-157, PCB-167 and PCB-189) substituted congeners that have been shown in experimental systems to exert a number of responses similar to those observed for 2,3,7,8-TCDD. There is evidence to suggest that there is a common mechanism of action of TCDD and these dioxin-like PCBs in biological systems, based on their binding to an intercellular protein, the Ah-receptor (Safe 1992, 1995). Table 5 is an estimation of toxic equivalency concentration (TEQ) of dioxin-like PCBs found in present study. The calculation is based on Van den Berg (Van den Berg *et al.* 1997). However, there is a major deficit in the estimation, because concentrations of non-ortho PCBs were below method detection limits, whereas PCB-126 and PCB-169 have a relatively greater toxic equivalent factor compared to other dioxin-like PCBs. As a result, the calculated TEQ would be underestimated and should be represented more precisely as WHO-mono-ortho-TEQ_{PCBs}. Be that as it may, the present estimated TEQ of 2.011 pg/g is much lower than that obtained from Japanese human adipose tissue (15.3 pg/g) (Choi *et al.* 2002). It is not unexpected because the actual concentration of PCBs in Japanese adipose tissue (1.71 μg/g fat) was 10-folder higher than results obtained in this study (0.19 μg/g fat) (Minh *et al.* 2000). In addition, the TEQ_{PCBs} obtained in present study are comparable to that obtained in human milk samples from Hong Kong (Soechitrain *et al.* 2003; Malisch and van Leeuwen 2003).

There is a severe lack of information concerning POPs in various ecological compartments in the Pearl River Delta region, which has undergone a very rapid socioeconomic change in the past 20 years. In order to provide more basic data for ecotoxicological and human health risk assessment of the region, a regional organization should be established for setting up a monitoring network using standardized methodologies, with vigorous quality assurance and quality control The more reliable data generated could be used to more accurately assess the fates and effects, including the transboundary movement of POPs in the region.

Acknowledgments. The authors would like to thank Hong Kong Baptist Hospital, Canossa Hospital, Caritas Hospital, Hong Kong Sanitarium Hospital and Union Hospital for the provision of samples and Angela Wong for technical support, This work was supported by Group Research–Central Allocation of the Research Grants Council, University Grants Committee of Hong Kong (No. HKBU-2/00 C).

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